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L8: Entry 3 of 235 File: USPT Aug 26, 2003

DOCUMENT-IDENTIFIER: US 6609411 B1
TITLE: Apparatus for removing water from dielectric oil in electrical power transformers

Abstract Text (1):
An apparatus for removing water from a dielectric oil which includes a vacuum pump (56) which militates against the introduction of air into the dielectric oil and a thin film capacitance sensor (48) for monitoring the amount of moisture present in the dielectric oil.

Brief Summary Text (2):
This invention relates to an apparatus for drying dielectric oils and more particularly to an apparatus for removing water from dielectric oil used in electrical power transformers.

Brief Summary Text (4):
A key component in delivering electrical energy to the consumer is the dielectric oil-filled power transformer. Electricity is typically generated at some location distant from the point of consumption. To deliver it economically, the voltage from the generator is increased to higher levels by step-up transformers for transmission to a number of substations where step-down transformers reduce the voltage for industrial and municipal use. Electricity is distributed at even lower voltages for domestic use. Transformers are critical links in the delivery of power from the source to the consumer in an economical and reliable fashion. Small power transformers are typically mounted on utility poles positioned along streets, at malls, and industrial sites, whereas moderate to large size units are located at substations and generating stations.

Brief Summary Text (5):
Transformers are primarily composed of conductors that may be copper or aluminum, and insulating materials that are typically mineral oil and paper. The mineral oil serves two functions: 1) as a coolant to minimize overheating of the transformer, and 2) as a dielectric providing sufficient strength to prevent dielectric breakdown between conducting parts at different electrical potentials and also between the energized parts and the grounded tank. The paper serves as an electrical insulator and provides mechanical support for the electrical conductor packages. A large transformer may contain 30,000 gal (113 550 L) of dielectric oil and 30,000 lbs (13 610 kg) of paper insulation.

Brief Summary Text (7):
In order for the transformer to operate properly, the insulating materials must be dried to a proper level. The dielectric breakdown voltage of oil is reduced with increasing water content. As dielectric breakdown voltage is also affected by the presence of particles, it can not be used to predict the water content.

Brief Summary Text (8):
Oil is typically dried to less than 10 ppm water by weight and can increase to 20-30 ppm in use depending upon the voltage class of the equipment. A worst case situation arises when the water content, even at low parts per million, becomes greater than that required for saturation of the oil, and free water is formed. This results in drastically reduced dielectric breakdown strength of the oil with the risk of failure of the transformer greatly increased.

Brief Summary Text (9):
The paper insulation must also be free of water to achieve good dielectric properties and enhance resistance to degradation. The concentration of water is usually between 0.1 to 0.5% by weight. The quantities of water in the paper insulation is much greater than that in the oil. When oil and paper are together, water will partition between them primarily based upon temperature.

Brief Summary Text (10):
As more demand or load is placed on a transformer, the insulating materials increase in temperature. The elevation in temperature forces water from the paper insulation into the dielectric oil. As demand is reduced and the transformer cools, the water migrates from the oil to the paper.

Brief Summary Text (14):
Transformers are tested at the factory to ensure drying procedures are adequate. Testing of dew point, vapor pressure, and electrical properties are used to assess the water content of the paper insulation before the transformer is filled with oil. Measurement of water in the oil is performed during and after filling of the transformer. In some cases the transformer may be shipped with dry air or nitrogen under slight positive pressure and then oil filled in the field.

Brief Summary Text (15):
Once the transformer is filled with oil, it is extremely difficult and almost impossible, for practical purposes, to obtain paper samples. Therefore, evaluation of the dryness of the paper insulation is

performed by external overall measurement of the electrical properties of the transformer winding insulations that are influenced by water, or by taking samples of oil, recording the oil temperature, and using appropriate correlation curves to determine water content of the paper and dielectric oil. The latter can be effectively performed only if the transformer has been maintained at a steady warm temperature for many days to allow the system to come to a steady state.

Brief Summary Text (16):
Oil from transformers in the field should be checked for water content to make sure the manufacturer properly dried the paper insulation, to see if a leak has occurred, and because insulation degradation results in water formation over long periods of time. Careful monitoring can help prevent the conditions that will result in the formation of free water above the saturation level in oil and subsequent failure of a transformer. A margin of safety is provided by maintaining the insulation dry enough so that under all operating conditions, the water in oil is at less than 50% saturation.

Brief Summary Text (17):
Presently, in order to effect the desired dehydration of the dielectric oil in an energized operating transformer involves a process wherein the transformer containing wet dielectric oil must be taken out of service. The dielectric oil is removed from the transformer and is serviced by heating the oil above about 200.degree. F. under high vacuum to remove built-up dissolved water. This is generally time consuming and accomplished by circulating the oil to be treated through a heating and evacuating system mounted on a mobile service truck. For large transformers, the drying process may require several attendants overseeing the removal, working in twelve hour shifts for a period of one week.

Brief Summary Text (18):
It is an object of the present invention to produce an apparatus for removing water from the dielectric oil in an energized electrical power transformer while the transformer is in service.

Brief Summary Text (19):
Another object of the invention is to produce an apparatus for removing water from the dielectric oil in an energized electrical power transformer including the vacuum pump for militating against air entering the transformer during the period the water is being removed from the dielectric oil.

Brief Summary Text (20):
Still another object of the invention is to produce an apparatus for removing water from the dielectric oil of an energized transformer including a monitor for sensing the water content of the dielectric oil before and after the oil is caused to be passed through the treating filter cartridges in the evacuated filter housing or vessel.

Brief Summary Text (22):
The above, as well as other objects of the invention, may be readily achieved by an apparatus for removing water from the dielectric oil in an electrical power transformer comprising: a pump for circulating the dielectric oil from a transformer and returning the same to the transformer; a filter in fluid communication with the pump for removing water from the dielectric oil; a vacuum pump in fluid communication with the filter for preventing air from being introduced into the transformer; and a sensor for monitoring the dryness of the oil after circulation through the filter.

Detailed Description Text (3):
Also, it has been found that dissolved water may be satisfactorily removed from the dielectric transformer oil being treated by utilizing filter cartridges 12 available from Velcon Filters, Inc., Colorado Springs, Colo. sold under the trademark Superdri. These cartridges may be of the particular construction as illustrated and described in U.S. Pat. No. 5,574,214. The cartridges 12 are designed to remove dissolved water from insulating a dielectric oil used in electrical transformers and reduce the water in the oil to <10 ppm without the necessity of utilizing ancillary heat and vacuum.

Detailed Description Text (9):
A flow meter 50 and a meter 52 for sensing the temperature of the treated dielectric oil are disposed in the line downstream of the sensor 48. Typically, the flow meter 50 is battery operated and is capable of reading the flow of the treated oil in gals./min. The temperature sensing meter 52 is normally capable of reading temperatures between 0.degree. and 250.degree. F.

Detailed Description Text (15):
As a safety precaution, a double walled hydraulic hose line is preferred for use between the dielectric oil outlet 18 of the transformer 20 and the manual valve 28 leading to the inlet of the pump 22; and inlet 40 of the transformer 20 and the outlet 16 of the filter vessel 10 generally commencing downstream of the flow meter 50 and the temperature gauge 52.

Detailed Description Text (16):
In operation, after the inlets and outlets of the transformer 20 and the filter vessel 10 are properly coupled, the pump 22 and the vacuum pump 56 are energized from an associated electrical power source, not shown. With the solenoid actuated valves 26, 54 in the normally opened position, the wet dielectric oil is caused to be pumped from the transformer 20 to the filter vessel 10 by the pump 22. Simultaneously, the vacuum pump 56 draws a vacuum in the filter vessel 10 to eliminate air entering the system.

Detailed Description Text (18):
During the treating of the dielectric oil, the vacuum pump 56 is operative to militate against the presence of air in the system which would otherwise adversely effect the efficiency of the water removed from the transient oil.

CLAIMS:

1. An apparatus for removing water from dielectric oil in an energized electrical power transformer comprising: a pump for circulating the dielectric oil from a transformer and returning the dielectric oil to the transformer; a filter in fluid communication with said pump for

removing water from the dielectric oil; a vacuum pump in fluid communication with said filter for preventing air from being introduced into the transformer; and a sensor for monitoring the dryness of the oil after circulation through said filter.

2. The apparatus for removing water from an energized electrical power transformer according to claim 1, further comprising a safety alarm for automatically isolating said pump for circulating the dielectric oil from the transformer in response to abnormal oil flow conditions.

4. The apparatus for removing water from an energized electrical power transformer according to claim 3, including a digital display for displaying the water content and the temperature of the dielectric oil.

5. The apparatus for removing water from an energized electrical power transformer according to claim 4, wherein said sensor includes at least one of an audible and a visual alarm energized when said sensor detects a water level in the dielectric oil that exceeds a preset level.

7. The apparatus for removing water from an energized electrical power transformer according to claim 1, including a co-axial hose interconnecting said pump for circulating the dielectric oil, said filter, and the transformer, wherein said co-axial hose includes a primary inner hose and a secondary outer hose.

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L9: Entry 6 of 63 File: USPT May 13, 2003

DOCUMENT-IDENTIFIER: US 6561010 B2
TITLE: Apparatus and method for fluid analysis

Brief Summary Text (6):
Traditionally, an oil sample has been taken from the lubricant reservoir on the engine being analyzed, and each of these parameters was then measured in the laboratory by different instruments for different purposes. Viscosity is measured with a viscometer and provides an indication of possible dilution of the oil by fuel or water. Viscosity can also indicate oil degradation from heat or oxidation. Chemical degradation of the oil (e.g., oxidation, nitration) is commonly determined by infrared (IR) spectrometric analysis, which may also be used to infer total acid number (TAN) and total base number (TBN) for the oil. Water in the oil may also be detected by IR analysis. Slow coolant leaks into the lubricating oil system may be detected by quantitative analysis of boron, chromium or other elements present in the coolant water as salts. Elemental analysis is typically accomplished by atomic emission spectrometry (AES) or other atomic spectroscopy methods, but may also be accomplished by X-ray fluorescence (XRF). Such analyses provide an indication of component wear according to the type and amount of metal(s) in the sample.

Brief Summary Text (9):
On-board or in situ machine fluid analysis has been investigated with several proposed approaches. For example, Voelker et al (U.S. Pat. No. 5,789,665) described a method and apparatus for determining deterioration of lubricating oils by measuring electrical properties of a polymeric matrix or by exploiting volumetric change behavior of the polymeric matrix in the form of beads. Disadvantages of this approach include that it responds only to a single parameter (free water) but does not quantify the free water, and there is a need to replace used polymer beads.

Brief Summary Text (10):
Freese et al. (U.S. Pat. No. 5,604,441) relies on measurement of changes in dielectric properties of a lubricant (oil) in a changing magnetic field. The change in dielectric properties indicates a change in oil condition. Dielectric constant is non-specific and at best may provide an indirect indication of oil degradation. The magnetic field is also used to attract and quantify ferromagnetic particles.

Brief Summary Text (11):
Finally, Boyle et al. (U.S. Pat. No. 5,964,318) designed a system to measure the level and quantity of lubricant in an engine lubricant reservoir. On-board in situ sensors are provided to measure the quantity of lubricant in the system, as well as the quality (temperature, pressure, dielectric and/or viscosity). If the quality drops below a predetermined level, the system diverts a portion of the lubricant to a reservoir for storage or reintroduction as a fuel additive, and a coincident addition of fresh lubricant to the system to maintain the desired level of lubricant. However, the apparatus/process disclosed in the '318 patent is a totally self-contained system; it does not provide an indication to those remotely monitoring engine health of the current status of lubricant within the engine--it is solely an internally-monitored lubricant quality indicator.

Brief Summary Text (19):
As used herein, the term or phrase "standard laboratory analysis parameter(s)" refers to parameters specified for direct determination of fluid or machine condition. More specifically, standard laboratory analysis parameter includes, but is in no way limited to, viscosity, low viscosity and high viscosity; pentane insolubles; soot, additive package (presence of chemical additives used to improve lubrication characteristics), oxidation or oil polymer breakdown products, nitration, sulfation, fuel dilution, water concentration; or concentration of specific elements including, but not limited to, iron, lead, copper, silicon, chromium, aluminum, silver, and zinc. In contrast, a non-standard parameter would be an indirect measure including, but not limited to, dielectric constant, polymer swelling, and combinations thereof and are specifically excluded from "standard laboratory analysis parameter".

Detailed Description Text (6):
Examples of standard laboratory analysis parameters for machine fluids are shown in Table I. Also shown are the meters that are used to determine these standard laboratory analysis parameters, both measured and derived, in accordance with the present invention. The standard laboratory analysis parameters for oil include, but are not limited to, viscosity; turbidity; particulate size and quantity; total acid number (TAN); total base number (TBN); water content (includes free water and dissolved water); concentrations of cooling water elements including, but not limited to, boron, magnesium, iodine and combinations thereof, wear metal including, but not limited to, iron, lead, copper, silicon, chromium, aluminum, silver, magnesium, tin, and zinc, and combinations thereof.

CLAIMS:

19. A machine fluid analysis system comprising: a plurality of different sensors contacting a fluid under pressure of a machine, wherein at least two of the plurality of sensors are selected from the group consisting of optical meter, viscometer, element meter, and particle counter; a controller operable to collect data from the plurality of sensors for transmission to a remote location; and a two-way wireless communicator coupled to the controller for receiving interrogation signals and for transmitting the collected data to the remote location; and a fluid cooler operably coupled to at least one of the sensors; wherein fluid is provided to different ones of the plurality of sensors at substantially different temperatures.

32. A fluid analysis system comprising: a plurality of different sensors contacting a fluid under pressure of a machine, wherein each of the plurality of sensors are operable to determine a different machine fluid parameter selected from the group consisting of: viscosity, pentane insolubles, soot, additive package, oxidation or oil polymer breakdown products, nitration, sulfation, fuel dilution, water concentration, and concentration of a specific element; a controller operable to collect data from the plurality of sensors for transmission to a remote location; and p1 a two-way wireless communicator coupled to the controller for receiving interrogation signals and for transmitting the collected data to the remote location; and p1 a thermally controlled compartment wherein at least one of the sensors is inside of and another is outside of the thermally controlled compartment whereby fluid is provided to different ones of the plurality of sensors at substantially different temperatures.

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L9: Entry 10 of 63 File: USPT Oct 1, 2002

DOCUMENT-IDENTIFIER: US 6459995 B1
TITLE: Electrical measurement of oil quality

Brief Summary Text (3):
It has been known for many years that the complex permittivity (or dielectric coefficient) of an engine lubricating oil changes with use, that is to say, both the real pan and the imaginary part change in response to changes in dissolved and suspended components of the oil. Such components are, for example, soot particles, water, acid combustion products, glycols, and ferrous and non ferrous metallic particles . In addition, oils often contain additives such as viscosity improvers and anti-oxidants which tend to break down with continued engine use, especially in the presence of water and metallic particles, which also accelerate the process of oxidation and general degradation.

Brief Summary Text (4):
It is also known that the reliability and longevity of an engine is crucially dependent upon the quality of its lubricating oil, and that an apparatus designed to detect some point at which the quality is deemed to be unacceptable would be desirable. In particular, when used in conjunction with a secondary bypass engine filter designed to remove particulate material down to 1 micron, such a device would be useful. Since such a filter may pass say 1% of the output from the oil pump, the differential pressure across the input and output of the filter is very low, making it difficult to measure. Consequently it is also difficult to know whether the filter element has become blocked. If this were to happen, however, the effect of the bypass filter in removing debris would be lost, and the concentration of contaminants would rise rapidly. Such a rise, or rate of change, could be detected by an oil quality monitor, enabling the filter or filter element to be replaced. If the oil quality monitor were to indicate poor quality, a sample may then be taken from the engine or machine, and sent to a suitable laboratory or facility for advanced spectrographic or chemical analysis, which may then reveal the presence of excessive soot, water, glycol, oxidation products, or metallic particles.

Brief Summary Text (7):
Advanced oil analysis as carried out by an accredited laboratory subjects oil samples to a battery of tests, one of which is often a basic measurement of dielectric properties, often carried out by hand. An oil quality monitor according to the invention may be incorporated into an automated production line. The invention may be adapted so that a sensing head is provided at the end of a slender flexible rod suitable for insertion into the dipstick orifice of an engine or machine to allow in situ measurement of oil quality in an engine or machine not otherwise fitted with an oil quality measuring device.

Brief Summary Text (9):
In U.S. Pat. No. 3,182,255, Hopkins et al. describe a device in which a bridge circuit is used to measure the AC impedance of one arm of the bridge, which contains a capacitive element whose capacitance changes with the dielectric strength (sic) of a drop of lubricating oil.

Brief Summary Text (10):
This device requires the physical removal of an oil sample from the vehicle, and makes no distinction as to whether the measured parameter is the real or the imaginary part of the permittivity. It can be shown that the impedance of a capacitor containing a dielectric depends, to first order, upon the real part, and to second order, upon the imaginary part, so that, even if no change occurs in the real part, there will nevertheless be a change in the modulus, or magnitude, of the permittivity, if there is a change in the lossiness of the dielectric, such as may occur through the presence of carbon particles. It is this magnitude which is usually referred to loosely as "dielectric constant". In another patent, U.S. Pat. No. 4,064,455, Hopkins et al. describe the use of an identical bridge circuit, but this time in conjunction with data storage and computational facilities.

Brief Summary Text (12):
In U.S. Pat. No. 4,733,556, Meitzler et al. describe a parallel plate capacitive sensor designed to fit between the engine block and the filter, where changes in the magnitude of capacitance are used to generate changes in the frequency of an associated oscillator. It is this change in frequency which is measured and subsequently compared, not with soot content of the oil, but with its viscosity. Although it is known that the complex permittivity of polar liquids will change with viscosity, it is also known that the viscosity will tend to increase with increasing soot concentration. This increase in viscosity is a macroscopic effect in the sense that a soot particle is many orders of magnitude larger than a molecule, and it is felt that measurement of dielectric constant is not a reliable indicator of viscosity in sooty oils.

Brief Summary Text (14):
In U.S. Pat. No. 5,134,381, Schmitz et al. describe the use of a concentric capacitive sensor along whose axis passes, a fuel/alcohol

mixture. Measurement of the capacitance of the sensor then provides the means whereby the alcohol content of the fuel may be determined, given a priori knowledge of the water content also. It appears that the capacitive sensor is excited by an external oscillator with the intention of measuring the impedance of the sensor and possibly also an associated phase shift.

Brief Summary Text (16):
In U.S. Pat. No. 5,272,444, Cox describes a method for measuring the water content and salinity (water cut) of a petroleum stream via measurement of temperature, resistivity and dielectric constant, but gives no details as to the mechanical arrangement of the sensor. It is clear however that the sensor is excited by an oscillator running at one of two fixed frequencies viz. 15 MHz and 30 MHz.

Brief Summary Text (17):
In U.S. Pat. No. 4,932,243, Suh et al. describe an online means for measuring the moisture content of a material, for example polymer pellets, using a capacitive sensor comprising three conductive concentric cylinders through which the material passes axially. The capacitance and dielectric loss are determined using "well known techniques" which are not detailed.

Brief Summary Text (19):
In U.S. Pat. No. 4,181,881, Preikschat describes an apparatus also intended to measure the so-called dielectric coefficient and conductivity of various materials. This appears to be a batch testing method, and precise details of the capacitive sensor are not provided, other than to describe it as an earthed rectangular box with an active centre electrode. The capacitive sensor is excited by means of a stable crystal oscillator, the bridge circuitry being designed to measure the phase and amplitude of the voltage across the sensor.

Brief Summary Text (21):
In GB 2249636, McBrearty describes an inline dielectric sensor using a form of interdigitating capacitor to measure the dielectric coefficient and loss factor of molten polymers. This is accomplished by exciting the sensor with a sine wave generator. In the document, it is stated that a current to voltage converter and a lock-in amplifier are used to measure the amplitude and phase of the resultant alternating current.

Brief Summary Text (22):
WO 96/28742 describes an apparatus intended specifically for on-line monitoring of engine lubricating oils in diesel engines, and discusses the necessity or desirability of carrying out continuous monitoring of the oil. In this apparatus, the fundamental principal is that of measuring the dielectric coefficient of the oil, but in order to extract the greatest amount of information from the sample, the apparatus uses an arrangement of electromagnets to concentrate ferrous particles in the vicinity of a flat interdigitating capacitive sensor. Although the interdigitating capacitor is an interesting and useful configuration, the given formula relating capacitance to the dimensions of the capacitor refers to a parallel plate configuration, and so appears to be inaccurate in that context. The capacitor forms part of an oscillator circuit whose frequency varies with the dielectric coefficient of the oil. Since no inductor is present in the block diagram or in the text, it is assumed that the circuit is found to be self resonant as a result of parasitic inductances or the self inductance of the capacitive sensor. The inventors state that "the sensor element is charged by an oscillator circuit . . . using a monostable multivibrator to generate an output signal at a frequency corresponding to the sensor element capacitance". This can be taken to mean that the oscillator frequency is determined directly by the sensor capacitance, or that the frequency of the oscillator is adjusted until it coincides with the self resonant frequency of the sensor. In any event, the measurand is the frequency, so the parameter actually being measured is the magnitude of the dielectric coefficient (sometimes referred to as "dielectric constant").

Brief Summary Text (23):
It is known that a few devices have attempted to correlate oil quality with dielectric coefficient by measuring the capacitance of a capacitor with the oil as a dielectric. This has been achieved by measuring either the change in AC impedance or by measuring the change in frequency when connected in an LC resonant circuit. However, in these cases what is actually being measured is the magnitude of the capacitance, which changes slightly with the lossiness Tan .delta. of the dielectric, but also changes with dielectric constant. Such devices therefore have the disadvantages of being sensitive to oil base type, and only being sensitive to the second order as regards the loss term Tan .delta..

Brief Summary Text (25):
The present invention provides apparatus for measuring oil quality based on the permittivity (dielectric coefficient) of the oil comprising a capacitive sensor for exposure to the oil, and an oscillator circuit including the sensor, characterised in that the oscillator circuit comprises an LC or crystal oscillator and provides an output signal, the amplitude of which is dependent upon the lossiness Tan .delta. of the oil, and measuring means that responds to the amplitude of said output signal as a measure of oil quality.

Brief Summary Text (27):
Thus, the output of the oscillator varies in response to changes in the lossiness of the dielectric medium (the oil), which in turn are determined principally by changes in the oil's soot content, acidity, and polar oxidation products. It is this change in the amplitude of the oscillator output which provides a measure of the oil quality.

Brief Summary Text (32):
The sensor is preferably incorporated in a sensor head which is generally concentric or radially symmetric. It is preferably perforated or slotted to allow the free passage of oil over the electrically active surfaces of the sensor. Typically, the sensor head is about 10 mm in diameter, being small enough to fit into a hole such as might be provided in an engine for an oil pressure switch, such as a 1/8" NPT (National Pipe Thread) or 1/4" BSP (British Standard Pipe) orifice. The associated oscillator electronics are located in the space behind the sensor head, which can take the form of a hollow hexagonal nut approximately 30 mm A/F by 20 mm deep. Since the

electronic circuitry is at approximately the same temperature as the oil, it comprises components which will operate in elevated temperatures, for example, up to 150.degree. C., and, optionally, which will also provide compensation to allow for temperature dependent changes in the dielectric medium.

Brief Summary Text (33):
It is known that changes in temperature affect electronic components such as transistors, inductors and capacitors, so that the output of the circuit, independently of the oil dielectric, is a function of temperature. The electrical properties of the oil itself are also affected by temperature. The most visible effect is the change in density, which is effectively linear over the range of interest, that is, from about 30.degree. C. to 150.degree. C. It follows that the concentration of contaminants, being inversely proportional to volume, will fall with increasing temperature. Simultaneously, however, the viscosity of the oil also falls with temperature, allowing greater freedom of motion for the constituent molecules, and it can be shown theoretically that the greater the average dipole moment of the liquid, the greater will be its dependence on temperature. In order to operate accurately over a wide range of temperatures, some form of compensation is necessary. Incorporated into the electronics is a small temperature sensor whose output, after suitable buffering, is passed out of the sensor head to a display unit.

Brief Summary Text (36):
Oils are generally a complex mixture of hydrocarbons and proprietary additives, such that the output of the oscillator differs slightly according to the precise formulation. Although it has been found in practice that the output differs by only a few percent to within one standard deviation over a wide range of different oils from different manufacturers (as shown in FIG. 10), calibration means is included to eliminate even this small source of error. When the vehicle or machine is serviced or supplied with fresh oil, the microprocessor may accept an input from a recessed switch or coded transmitter when the correct operating temperature has been reached, such that that particular value is held in memory, and therefore becomes the baseline against which all subsequent readings will be compared.

Drawing Description Text (12):
FIG. 9 shows a number of curves of sensor output against temperature for engine oils of different levels of contamination,

Detailed Description Text (2):
Mineral lubricating oil is an essentially non-polar liquid dielectric with very high resistivity that is to say, the passage of non alternating conduction current through it is negligible, even when loaded with conductive particles such as soot. It may be characterised by its permittivity, which is in general complex, consisting of a real and an imaginary part, that is

Detailed Description Text (4):
where j=(-1) and Tan .delta.=.epsilon."/.epsilon.'. The phase angle .delta. is a measure of the lossiness, or dissipation factor, of the dielectric, and will determine the maximum amplitude attainable by a tuned circuit of which it forms a part.

Detailed Description Text (6):
where C.sub.0 is the value of the capacitance with an otherwise lossless dielectric. It can be seen that the magnitude, or modulus, of the capacitance is therefore

Detailed Description Text (8):
When the sensing element is a simple capacitor such as described, the idea of a lossy dielectric is intuitively clear, and the mathematical analysis is straightforward. However, the sensing element may also take the form of a short antenna radiating into the lossy dielectric medium, where the characteristics of the medium influence the loading on the antenna In this case the analysis, in which the near field components of the antenna are important, is more complicated, but the effect on the oscillator is the same, that is, the voltage and current will change with changes in the value of Tan .delta. of the medium. These changes may be measured and interpreted as changes in the quality of the oil. In an unused lubricating oil at a typical operating frequency, Tan .delta. is typically around 0.01, increasing to perhaps 0.1 for a heavily contaminated sample, while .epsilon.' is typically 2.25 to 2.45. For small concentrations of soot up to a few percent, Tan .delta. is approximately proportional to soot concentration, while the corresponding change in .epsilon.' is only a few percent at most. This means that Tan .delta. is the most suitable parameter for indicating oil quality, being insensitive to variations in the composition of clean oils, and having the greatest rate of change during use and subsequent contamination.

Detailed Description Text (17):
The Tan .delta. term is sensed in any of a variety of ways, of which one is the measurement of the potential difference across a tuned circuit for example as shown in FIG. 1. It is well known that the impedance of a parallel LC or RLC circuit increases as the exciting frequency approaches the resonant frequency (for small Tan .delta. phase resonance and amplitude resonance are very nearly the same, the former being defined as the point at which the reactance, or imaginary part of the impedance, is zero, while the latter is the point at which the amplitude is a maximum), and that the potential, or voltage across the circuit increases in the same proportion. This apparent amplification is often referred to as the "Q" of the circuit, which is generally the ratio of reactance to resistance in an RLC circuit, but which in the context of a lossy dielectric is simply 1/Tan .delta..

Detailed Description Text (33):
In the annular region of a concentric capacitor, the electric field is essentially uniform, and is confined to the volume between the electrodes. Any change in the dielectric medium will be reflected by a corresponding change in the complex capacitance. If the outer earthed part of the capacitor is removed completely, the inner element will still radiate into the dielectric medium, and the impedance of this element, now behaving like an electrically short antenna, is dependent on its dimensions, the frequency of operation, and the electrical characteristics of the medium. It is therefore not essential for the sensing element to be in the form of a capacitor in which the field is totally contained, and it may simply take the form of a short stub. In

constructing a derivative of the sensor for use in a test laboratory, it may be desirable for the sensing element to be as open as possible for ease of cleaning, but consistent with the need to keep radiated energy to a minimum and to allow the sensor to be insensitive to changes in the geometry and material of the vessel in which it is immersed. This requirement may be met by the provision of one or more grounded pins or elements in the vicinity of the active or live sensing element.

Detailed Description Text (34):
In a second embodiment, the sensing head differs in that the outer cylinder is replaced by an arrangement of vertical pins such that the alternating electromagnetic field around the central conductor links with the pins. FIG. 3 shows a view of this sensor with four grounded pins 50 in place of the coaxial outer conductor. It can be seen that the central conductor 52 is, in effect, a short antenna radiating into the dielectric medium. In a third embodiment, the sensing head (not shown) differs in that there is no grounded outer portion at all, this being provided by the engine block itself, or by the hardware (such as a sump, for example) into which the sensor is screwed. In this third embodiment the performance of the device would be dependent upon the precise geometry of the said hardware, and the frequency of operation is determined principally by the secondary coupling and feedback capacitors 4, 5 and 6.

CLAIMS:

16. Apparatus as claimed in claim 1, in which the sensor is intended to radiate into the oil dielectric medium like a short antenna or dielectric probe.

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L9: Entry 12 of 63 File: USPT Sep 10, 2002

US-PAT-NO: 6449580
DOCUMENT-IDENTIFIER: US 6449580 B1
TITLE: Evaluating properties of oil using dielectric spectroscopy
DATE-ISSUED: September 10, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bardetsky; Alexander	Cincinnati	OH		
Brovkov; Vladimir	Odessa			UA

ASSIGNEE-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY	TYPE CODE
Entek IRD International Corporation	Milford	OH			02

APPL-NO: 09/075622 [PALM]
DATE FILED: May 11, 1998

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US-CL-CURRENT: 702/130; 702/127, 702/136, 702/137, 73/32R
FIELD-OF-SEARCH: 702/50, 702/52, 702/81-84, 702/100, 702/113, 702/114, 702/130, 702/136, 702/137, 73/1.02, 73/32R, 73/54.01, 73/54.02, 73/53.05, 73/54.42, 340/603, 324/204, 324/553, 324/663, 324/664, 324/670, 324/685
PRIOR-ART-DISCLOSED:

U.S. PATENT DOCUMENTS

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PAT-NO	ISSUE-DATE	PATENTEE-NAME	US-CL
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3933030	January 1976	Forster et al.	73/32R
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ABSTRACT:

A working fluid of a mechanical system is analyzed by measuring the permittivity of the working fluid as the temperature of the working fluid is varied over a range. Within this temperature range, a special temperature is identified, at which the rate of change of the permittivity over temperature is at a maximum. Subsequently, the viscosity, acid content, moisture content and density of the working fluid are determined from the special temperature, rate of change of permittivity at the special temperature, permittivity of the special temperature, and rate of change of permittivity above the special temperature, respectively. To ensure accurate determination of the special temperature and other parameter values, a curve-fitting technique is used, in which measurements of permittivity over the temperature range are fitted to a mathematical model of the expected curve, and this mathematical model is used to identify the various parameter values. Apparatus for performing this analysis method may be in the form of a desk-top oil analyzer for use in an on-site application, or an integrated analysis device suitable for mounting directly to the mechanical system, e.g., in the form of an adapter insertable between the oil filter and oil filter mounting. The working fluid being analyzed may be oil, hydraulic fluid, or any other fluid used in a mechanical system which is subject to contamination and degradation.

105 Claims, 15 Drawing figures